

Helminth Community Structure and Pattern in Sympatric Populations of Double-Crested and Neotropical Cormorants

ALAN M. FEDYNICH,^{1,3} DANNY B. PENCE,¹ AND JAMES F. BERGAN²

¹ Department of Pathology, Texas Tech University Health Sciences Center, 3601 4th Street, Lubbock, Texas 79430 and

² The Nature Conservancy of Texas, P.O. Box 163, Collegeport, Texas 77428

ABSTRACT: Helminth communities of double-crested (*Phalacrocorax auritus*) and neotropical (*Phalacrocorax brasilianus*) cormorants from the midcoast of Texas were examined. Twenty-one helminth species were found; 17 species occurred in each host species, and 13 species co-occurred in both host species. The mean number of helminth species was similar, averaging 5.9 ± 0.4 (SE) and 5.8 ± 0.7 species in double-crested and neotropical cormorants, respectively. Helminth infracommunities were depauperate, particularly in commonly utilized microhabitats. Eleven common species were found, in which 9 and 10 species occurred in double-crested and neotropical cormorants, respectively. Of these, the prevalence of *Ascocotyle* sp. 2 was higher in double-crested cormorants, whereas the prevalence of *Capillaria contorta* was higher in neotropical cormorants. Eight species (*Ascocotyle* sp. 2, *Austrodiplostomum mordax*, *Paradilepis caballeroi*, *Capillaria spiculata*, *Contracaecum spiculigerum*, *Syncyrua squamata*, *Tetrameres microspinosa*, and *Andracantha grvida*) were common species in both host populations. The abundance of helminths was similar between double-crested and neotropical cormorants, averaging 134.0 ± 20.2 and 166.9 ± 23.2 helminth individuals, respectively. Of the 11 common species, rank abundances varied between host infrapopulations for 2 species; *C. contorta* was higher in neotropical cormorants, whereas *Desmiodocerca skrjabini* was higher in double-crested cormorants. For the 11 common species collectively, rank abundance was higher in neotropical cormorants. Our results suggest that helminth component communities in double-crested and neotropical cormorants occurring in coastal Texas largely share similar characteristics in structure and pattern.

KEY WORDS: community ecology, component communities, cormorants, helminths, *Phalacrocorax auritus*, *Phalacrocorax brasilianus*.

Helminth component communities in migratory avifauna frequently are species rich and diverse (Wallace and Pence, 1986; Fedynich and Pence, 1994), which presumably results from host vagility. Fedynich et al. (1996) demonstrated also that helminth communities in a nonmigratory host are likely influenced by temporally sympatric congeneric hosts.

The double-crested cormorant (*Phalacrocorax auritus*) (Lesson) [120.] is a common species in North America that overwinters on the Texas coast. The neotropical cormorant (*Phalacrocorax brasilianus*) (Gmelin) [121.] is a permanent resident of coastal Texas, which represents the northernmost extension of its geographic range in North America (del Hoyo et al., 1992).

The present study was initiated to compare the helminth communities of 2 related species of cormorants that regularly cooccur. Specifically, our

objectives were to (1) determine the helminth fauna of double-crested and neotropical cormorants from coastal Texas, (2) examine the structure and pattern of helminth communities found in both host infrapopulations, and (3) relate these findings to host–parasite interactions.

Materials and Methods

Cormorants were collected in coastal areas of Matagorda County, Texas (28°24'N, 96°09'W). Twelve each of double-crested and neotropical cormorants were collected by shooting, primarily during fall and winter (double-crested cormorants: January 1995, $n = 7$; February 1996, $n = 6$; neotropical cormorants: August 1994 to January 1995, $n = 5$; May 1995, $n = 1$; February 1996, $n = 5$) when both species co-occurred on the study area. Neotropical cormorants are year-round residents on the study area, whereas double-crested cormorants are only winter residents. All cormorants collected were subadults or adults. Cormorants were frozen and stored at -10°C until necropsy. Cormorants were collected in accordance with established guidelines and protocols of U.S. Fish and Wildlife Service scientific collection permit PRT-693859 and Texas Parks and Wildlife Department scientific permit SPR-0490-065.

Helminths were collected, counted, preserved, and examined according to methods described in Wallace and

³ Corresponding author and present address: Dr. Alan Fedynich, Caesar Kleberg Wildlife Research Institute, Texas A&M University–Kingsville, Campus Box 218, Kingsville, Texas 78363.

Pence (1986). Microhabitats examined for helminths included the trachea, esophagus, proventriculus, gizzard lining, heart, lung, kidney, liver, gallbladder, pancreas, spleen, small intestine, large intestine, ceca, cloaca, mesenteric veins, reproductive tract, and body cavity.

Helminths were identified following the taxonomic keys of Skrjabin et al. (1957), Sonin (1966, 1968), Yamaguti (1958, 1959, 1961, 1971), McDonald (1974), Chabaud (1975), and Anderson and Bain (1976). The identification of *Paradilepis caballeroi* and *Andracantha grvida* was based on the descriptions of Rysavy and Macko (1971) and Schmidt (1975), respectively. Our specimens of *Drepanocephalus spathans* most closely resemble those described by Dietz (1909) and redescribed by Rietschel and Werding (1978), the description of 2 closely related new species of the genus *Drepanocephalus* from *P. brasiliensis* (=their *Phalacrocorax olivaceus*) by Nasir and Marval (1968) and Rietschel and Werding (1978), respectively, notwithstanding. Representative specimens of helminths are deposited in the United States National Parasite Collection, Beltsville, Maryland 20705 (USNPC Nos. 86718–86741). Host taxonomy, including the World List Numbers in brackets following the scientific names, is according to Sibley and Monroe (1990).

The terms *prevalence*, *intensity*, and *abundance* follow the definitions of Margolis et al. (1982). Habitat is defined by Whittaker et al. (1973); in relation to helminths, habitat refers to the host individual. Microhabitat refers to anatomical localities within the host. Common helminth species were arbitrarily defined as those species with $\geq 25\%$ prevalence; all other species were considered uncommon. Helminth infracommunity refers to all infrapopulations of helminth species occurring within an individual host (Holmes and Price, 1986). The component community is defined as all infrapopulations of helminth species occurring in all host individuals sampled from a particular host infrapopulation (Gray et al., 1989).

We compared the influence of host species on helminth community structure and pattern. Frequency data were analyzed with log-linear models (CATMOD; SAS Institute Inc., 1985a) to determine if the prevalence of the common helminth species varied between host infrapopulations. The Jaccard's coefficient of similarity (Jaccard, 1912) was used to measure the similarity of shared helminth species between host infrapopulations. The numerical dominance index (DI) of Leong and Holmes (1981) was used to rank helminth species by the number of individuals that each species contributed to the total number of individuals within each host infrapopulation.

The Brillouin's index (BI), appropriate for fully censused communities, was used to quantify diversity (Pielou, 1975) for each helminth infracommunity. Since BI measures diversity for a fully censused collection at the infracommunity level, and each numerically different BI value is significantly different from all other BI values, there is no significance test to compare multiple collections (Magurran, 1988). An evenness index (EI), based on the ratio of BI/BI_{\max} (where BI_{\max} = maximum diversity possible given the number of species and the number of individuals in a particular collection), was computed to better interpret BI values (Pielou, 1975). Summary data of BI and EI are presented as range, median, and the 25 to 75% quantiles (Pence, 1990).

The frequency distribution pattern of abundance for the

collective common species and for each of the common species was tested for normality (PROC UNIVARIATE NORMAL; SAS Institute Inc., 1985a). Because a non-normal distribution pattern (overdispersion) occurred for most of the common species, abundance values were rank transformed (PROC RANK; SAS Institute Inc., 1985b) prior to further statistical analyses. Rank-transformed abundance values were examined for the main effect of host species, with 1-way analysis of variance (ANOVA; SAS Institute Inc., 1985b) for each common helminth species and with multivariate analysis of variance (MANOVA; SAS Institute Inc., 1985b) for the collective common species. Descriptive statistics are presented as a mean ± 1 SE.

Results

Twenty-one helminth species (11 trematodes, 1 cestode, 8 nematodes, and 1 acanthocephalan) were found in 7 microhabitats from 24 cormorants (Table 1). Seventeen helminth species were found in both the double-crested and neotropical cormorant infrapopulations, respectively (Table 1). Jaccard's index was 0.62, indicating a lack of helminth species co-occurrence between host infrapopulations. Only 13 species co-occurred in both host infrapopulations (Table 1). Helminth infracommunities in double-crested and neotropical cormorants averaged 5.9 ± 0.4 and 5.8 ± 0.7 species, respectively, and were similar ($P = 0.86$).

In both hosts, the proventriculus, esophagus, stomach, small intestine, and large intestine were the most common microhabitats utilized by helminths. However, there was a disparity of helminth species across available microhabitats. At the infracommunity level, 1 to 5 (median = 2) nematode species co-occurred in the combined microhabitats of the proventriculus, esophagus, and stomach in each of the 24 hosts examined, and 3 neotropical cormorants also had a trematode species (*Pseudopsilostoma varium*). In double-crested cormorants, there were 1, 4, 5, and 2 infracommunities occurring in the combined microhabitats of the small and large intestine, with 4, 3, 2, and 1 representatives of each of the 4 major helminth groups (1 to 5 trematodes, 1 cestode, 1 nematode, and 1 acanthocephalan species). For helminth infracommunities occurring in these microhabitats in neotropical cormorants, there were 3, 3, 3, and 3 infracommunities, with 4, 3, 2, and 1 representatives, respectively (1 to 2 trematodes, 1 cestode, 1 nematode, and 1 acanthocephalan species).

Eleven common helminth species were found, in which 9 and 10 species occurred in double-crested and neotropical cormorants, respectively. The prevalence of *Ascocotyle* sp. 2 was higher (P

Table 1. Helminths from double-crested and neotropical cormorants collected in Matagorda County, Texas.

Helminth species *	Double-crested cormorant (n = 12)						Neotropical cormorant (n = 12)					
	Prevalence			Prevalence								
	No. infected (%)	Intensity		Abundance		No. infected (%)	Intensity		Abundance			
		$\bar{x} \pm SE$	Range	$\bar{x} \pm SE$	Total		$\bar{x} \pm SE$	Range	$\bar{x} \pm SE$	Total		
DIGENEA												
<i>Amphimerus</i> sp. (L)	2 (17)	1.0	1	0.2 \pm 0.1	2	0						
<i>Ascochyte</i> sp. 1† (SI, LI)	2 (17)	6.0	6	1.0 \pm 0.7	12	1 (8)	1.0	1	0.1 \pm 0.1	1		
<i>Ascochyte</i> sp. 2‡ (SI, LI)	8 (67)	21.0 \pm 9.7	2–83	14.0 \pm 7.0	168	3 (25)	47.7 \pm 39.2	5–126	11.9 \pm 10.4	143		
<i>Ascochyte</i> sp. 3 (LI)	2 (17)	2.5 \pm 1.5	1–4	0.4 \pm 0.3	5	0						
<i>Austrodiplasionum mordax</i> Szidant and Nani, 1951 (USNPC 86718, 86724)§ (SI, LI)	4 (33)	4.2 \pm 1.6	1–8	1.4 \pm 0.8	17	4 (33)	1.0	1	0.3 \pm 0.1	4		
<i>Drepanocephalus spatians</i> Dietz, 1909 (USNPC 86719, 86725) (SI)	1 (8)	1.0	1	0.1 \pm 0.1	1	1 (8)	14.0	14	1.2 \pm 1.2	14		
<i>Hysteromorpha triloba</i> (Rudolphi, 1819) Lutz, 1931 (USNPC 86726) (SI)	0					1 (8)	5.0	5	0.4 \pm 0.4	5		
<i>Maritrema</i> sp.¶ (SI, LI)	1 (8)	1.0	1	0.1 \pm 0.1	1	1 (8)	15.0	15	1.2 \pm 1.2	15		
<i>Mesophorodiplostomum pricei</i> (Krull, 1934) Dubois, 1936 (USNPC 86720) (SI)	1 (8)	7.0	7	0.6 \pm 0.6	7	0						
<i>Phocitremonoides butionis</i> Martin, 1950 (USNPC 86721, 86727) (SI, LI)	1 (8)	51.0	51	4.2 \pm 4.2	51	1 (8)	1.0	1	0.1 \pm 0.1	1		
<i>Pseudopistolostoma variatum</i> (Linton, 1928) Yamaguti, 1958 (USNPC 86728) (E, P, S)	0					3 (25)	27.7 \pm 25.2	1–78	6.9 \pm 6.5	83		
CESTODA												
<i>Paradilepis caballeri</i> Rysavy and Macko, 1971 (USNPC 86722, 86729) (SI)	3 (25)	2.3 \pm 1.3	1–5	0.6 \pm 0.4	7	6 (50)	13.5 \pm 8.2	1–53	6.7 \pm 4.4	8		
NEMATODA												
<i>Capillaria contorta</i> (Creplin, 1839) Yamaguti, 1935 (USNPC 86731, 86737) (E)	2 (17)	1.5 \pm 0.5	1–2	0.2 \pm 0.2	3	10 (83)	3.8 \pm 0.6	1–6	3.2 \pm 0.7	38		
<i>Capillaria spiculata</i> Freitas, 1933 (USNPC 86732, 86738) (LI)	8 (67)	3.9 \pm 1.3	1–9	2.6 \pm 1.0	31	8 (67)	3.9 \pm 1.5	1–14	2.6 \pm 1.1	31		

Table 1. Continued.

Helminth species*	Double-crested cormorant (n = 12)						Neotropical cormorant (n = 12)					
	Prevalence						Prevalence					
	No. infected (%)	Intensity		Abundance			No. infected (%)	Intensity		Abundance		
		$\bar{x} \pm SE$	Range		$\bar{x} \pm SE$	Total		$\bar{x} \pm SE$	Range		$\bar{x} \pm SE$	Total
<i>Contracaecum spiculigerum</i> (Ruddphi, 1809) Ralliet and Henry, 1912 (USNPC 86733, 86739) (E, P, S) <i>Desmitocercella skrjabini</i> Guschan- skaja, 1949 (USNPC 86734) (LU, S) <i>Syncaecia squamata</i> (Linstow, 1883) Wong et al., 1986 (USNPC 86735, 86740) (E, P, S) <i>Syngamus</i> sp. (DW) <i>Synhinanthus</i> sp. (E) <i>Tetrameres microspinosus</i> Vigneras, 1935 (USNPC 86736, 86741) (P)	12 (100) 4 (33) 4 (33) 0 0	83.9 \pm 14.2 16.0 \pm 8.7 2.2 \pm 0.9	11-177 1-32 1-5	83.9 \pm 14.2 5.3 \pm 3.5 0.7 \pm 0.4	1,007 64 9	12 (100) 0 3 (25) 1 (8) 1 (8)	101.0 \pm 17.7 2.7 \pm 1.7 1.0 2.0	16-230 1-6 1 2	101.0 \pm 17.7 0.7 \pm 0.5 0.1 \pm 0.1 0.2 \pm 0.2	1,212 64 8 1 2		
ACANTHOCEPHALA <i>Andracantha gravida</i> (Alegret, 1941) Schmidt, 1975 (USNPC 86723, 86730) (SI, LI)	8 (67)	2.0 \pm 0.3	1-3	1.3 \pm 0.3	16	7 (58)	47.4 \pm 18.9	4-132	27.7 \pm 12.8	332		32

* DW, decantation wash; E, esophagus; L, liver; LI, large intestine; LU, lung; P, proventriculus; S, stomach; SI, small intestine.
† *Ascocoyle* (*Ascocoyle*) sp.
‡ *Ascocoyle* (*Leigha*) sp.
§ U.S. National Parasite Collection specimen accession numbers, double-crested and neotropical cormorants, respectively.
|| Immature individuals only.

Table 2. Dominance index values generated for helminth species from 12 double-crested and 12 neotropic cormorants collected in Matagorda County, Texas.

Double-crested cormorant		Neotropic cormorant	
Helminth species	DI	Helminth species	DI
<i>Contracaecum spiculigerum</i>	62.6	<i>Contracaecum spiculigerum</i>	60.5
<i>Tetrameres microspinosa</i>	12.9	<i>Tetrameres microspinosa</i>	16.6
<i>Ascocotyle</i> sp. 2	10.4	<i>Ascocotyle</i> sp. 2	7.1
<i>Desmidocercella skrjabini</i>	4.0	<i>Pseudopsilostoma varium</i>	4.1
<i>Phocitremonides butionis</i>	3.2	<i>Capillaria contorta</i>	1.9
<i>Capillaria spiculata</i>	1.9	<i>Andracantha grvida</i>	1.6
<i>Austrodiplostomum mordax</i>	1.1	<i>Capillaria spiculata</i>	1.5
<i>Andracantha grvida</i>	1.0	<i>Maritrema</i> sp.	0.1
<i>Ascocotyle</i> sp. 1	<0.1	<i>Drepanocephalus spathans</i>	0.1
<i>Syncuaria squamata</i>	<0.1	<i>Paradilepis caballeroi</i>	<0.1
<i>Paradilepis caballeroi</i>	<0.1	<i>Syncuaria squamata</i>	<0.1
<i>Mesophorodiplostomum pricei</i>	<0.1	<i>Hysteromorpha triloba</i>	<0.1
<i>Ascocotyle</i> sp. 3	<0.1	<i>Austrodiplostomum mordax</i>	<0.1
<i>Capillaria contorta</i>	<0.1	<i>Synhimanthus</i> sp.	<0.1
<i>Amphimerus</i> sp.	<0.1	<i>Ascocotyle</i> sp. 1	<0.1
<i>Drepanocephalus spathans</i>	<0.1	<i>Phocitremonides butionis</i>	<0.1
<i>Maritrema</i> sp.	<0.1	<i>Syngamus</i> sp.	<0.1

< 0.05) in double-crested cormorants than in neotropic cormorants, whereas prevalence of *Capillaria contorta* was higher ($P < 0.003$) in neotropic cormorants. Eight species (*Ascocotyle* sp. 2, *Austrodiplostomum mordax*, *P. caballeroi*, *Capillaria spiculata*, *Contracaecum spiculigerum*, *Syncuaria squamata*, *Tetrameres microspinosa*, and *A. grvida*) were common species in both host infrapopulations.

We found 3,611 helminth individuals, of which 1,608 and 2,003 occurred in double-crested and

neotropic cormorants, respectively (Table 1). The abundance of helminths was similar ($P = 0.31$) between double-crested and neotropic cormorant infrapopulations, averaging 134.0 ± 20.2 and 166.9 ± 23.2 helminth individuals, respectively. Of the 11 common species, rank abundance varied between host infrapopulations in only 2 species: *C. contorta* was higher ($P < 0.0001$) in neotropic cormorants, whereas *Desmidocercella skrjabini* was higher ($P < 0.03$) in double-crested cormorants. For the 11 common species collectively (MANOVA), rank abundance was higher ($P < 0.02$) in neotropic cormorants.

The 9 and 10 commonly occurring species in double-crested and neotropic cormorants, respectively, accounted for 95 and 94% of all helminth individuals found in each respective host species. *Contracaecum spiculigerum* dominated the helminth component community in both hosts, accounting for 63 and 60% of all helminth individuals found in double-crested and neotropic cormorants, respectively (Table 2). *Tetrameres microspinosa* and *Ascocotyle* sp. 2 also were important (≥ 10 DI value) species in double-crested cormorants, whereas *T. microspinosa* was numerically important in the helminth component community of neotropic cormorants (Table 2).

Median BI values of double-crested and neotropic cormorants were 0.99 and 0.57, respectively (Fig. 1). Helminth infracommunities in both host species demonstrated a substantial lack of diver-

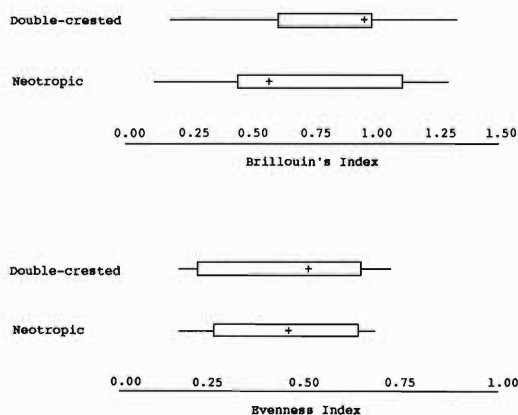


Figure 1. Brillouin's and evenness index values generated from helminth infracommunities, presented as box plots representing median (+), range (—), and the 25 to 75% quantiles (□), for cormorants collected in Matagorda County, Texas.

Table 3. The *F* statistics and *P* values for the main effect of host species from 1-way ANOVA and MANOVA for the ranked abundance of 11 common helminth species from 24 cormorants (12 double-crested and 12 neotropical) collected in Matagorda County, Texas.

Helminth species	<i>F</i>	<i>P</i>
ANOVA		
<i>Ascoctyle</i> sp. 2	3.03	0.0958
<i>Austrodiplostomum mordax</i>	0.17	0.6874
<i>Pseudosilostoma varium</i>	3.64	0.0694
<i>Paradilepis caballeroi</i>	2.27	0.1463
<i>Capillaria contorta</i>	22.41	0.0001
<i>Capillaria spiculata</i>	0.01	0.9088
<i>Contracaecum spiculigerum</i>	0.85	0.3670
<i>Desmidocercella skrjabini</i>	5.44	0.0293
<i>Syncauria squamata</i>	0.18	0.6750
<i>Tetrameres microspinosa</i>	<0.01	0.9543
<i>Andracantha gravis</i>	0.12	0.7279
MANOVA	3.40	0.0229

sity, with median EI values of 0.52 and 0.48 for double-crested and neotropical cormorants, respectively (Fig. 1).

Table 3 lists the *F* statistics and *P* values for the main effect of host species from 1-way ANOVA and MANOVA for the ranked abundance of 11 common helminth species from 24 cormorants collected in Matagorda County, Texas.

Discussion

We found helminth communities in double-crested and neotropical cormorants shared similar characteristics in community structure and pattern. These similarities were reflected in species richness, diversity, prevalence, numerical dominance, abundance, and number of shared common helminth species. Differences in helminth communities between host infrapopulations largely resulted from the lack of co-occurrence of 2 common and 6 uncommon helminth species.

One factor often considered to contribute to diverse helminth communities is host vagility, in which hosts that temporally occupy different habitats are exposed to a greater number of potentially infective parasites (Kennedy et al., 1986). This was a likely factor contributing to the large, species-rich, and diverse communities found in several migratory waterfowl species (Wallace and Pence, 1986; Fedynich and Pence, 1994). In our study, in which the double-crested cormorant is migratory and the neotropical cormorant is a permanent resident, migratory status did not appear to significantly alter helminth community structure and pat-

tern between host infrapopulations. This may be the result of both hosts utilizing the same food resources in coastal Texas. Also, helminth species found in cormorants may have parasitic larval stages that are intermediate host generalists, which infect a range of the respective prey items preferred by each cormorant species.

Kennedy et al. (1986) suggested hosts that have generalist diets tend to have diverse helminth communities, whereas hosts that feed selectively tend to have helminth communities that are dominated by large infrapopulations of a few parasite species. Stock and Holmes (1987) found broad diets in 3 of 4 grebes (Podicipedidae) led to diverse helminth communities. We found relatively low BI and EI values, which is reflective of the lack of diversity and equitability among helminth species within infracommunities in both host species examined in this study. This also was apparent when examining DI values for the helminth component communities in which only a few helminth species dominated (i.e., *C. spiculigerum* and *T. microspinosa*) in both host species. While there are few or no detailed studies on food habits of these 2 sympatric cormorant species in coastal areas of Texas (Morrison et al., 1977; King, 1989), both host species are considered to prey almost exclusively upon small fish (del Hoyo et al., 1992). Thus, our results appear to support the hypothesis of Kennedy et al. (1986) that helminth communities found in avian hosts that are food specialists are more likely to be species-poor and lack diversity than those hosts that are food generalists.

Acknowledgments

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